



The University of Texas at Austin
**Aerospace Engineering
and Engineering Mechanics**
Cockrell School of Engineering

Orbital Space – The Next Resource for Humanity to Exhaustively Exploit and Litter

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Space Situational Awareness and Space Traffic Management



SSA: The “Why”

Space Hazard “A Harsh Environment”

The space environment is hostile and hazardous

- Electronics upset
- Materials age
- Radio waves degrade

The space environment affects the dynamic behavior of objects

The environment needs to be understood and managed

Space Hazards “The Safety of Flight”

There are many space objects—many dead, some not

- Paths only approximately known
- Space is more crowded today

Space objects are hazardous to each other

- The probability is low, but the consequences are very high!

Traffic management of space congestion needs to assure safe operations, security, and sustainability

Space Threats “The Adversary”

Space is contested by adversaries today

- The required methods to address the threat are new
- The methods cross many phenomenologies and disciplines
- As long as we do not fully understand and measure the space domain, there will be places to hide and an ability for us to be deceived!!!

The threat is real, and growing

- We must be able to attribute cause of behavior: intentional vs unintentional

The threat must be detected, understood, and addressed

To Know it, you MUST Measure it; to Understand it, you MUST Predict it!



SSA: The “What” it should provide

- Transparency
 - Open and accessible space object and event data sharing
- Accountability
 - We must be able to monitor all behavior and given the evidence, come to common conclusions and infer similar causal relationships
- Predictability
 - Communication
 - Preemptive sharing of details (registering events) for planned events like maneuvers, launches, deployments, etc.
 - Cultural Competency
 - What is Sharia interpretation of the UN LTS Guidelines?
 - Do Israeli satellites maneuver on Shabbat?
 - Bottom Line: Can we predict what any space actor will do for any given space event?
 - Accurate and precisely modeled astrodynamics and space events
 - Ephemerides and related parameters
 - Space weather predictions



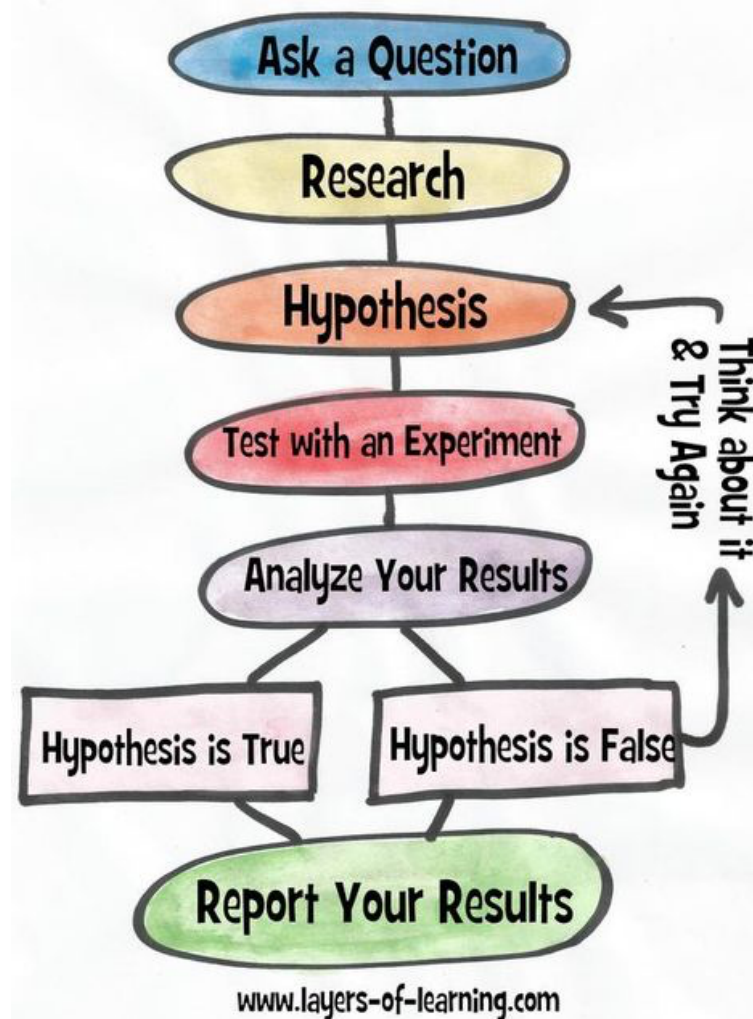
Essential Ingredients For Success

- Independent Space Object and Event Behavior Quantification, Monitoring, and Assessment
 - Collectively produce the evidence upon which to measure orbital safety, space security, and operational sustainability
- Sustainability Metrics
 - Space Traffic Footprint (STF)
 - Orbital Capacity
 - Space Sustainability Rating
- Development and Implementation of Best Practices and Standards
 - UN COPUOS
 - IADC
 - ISO
 - AIAA

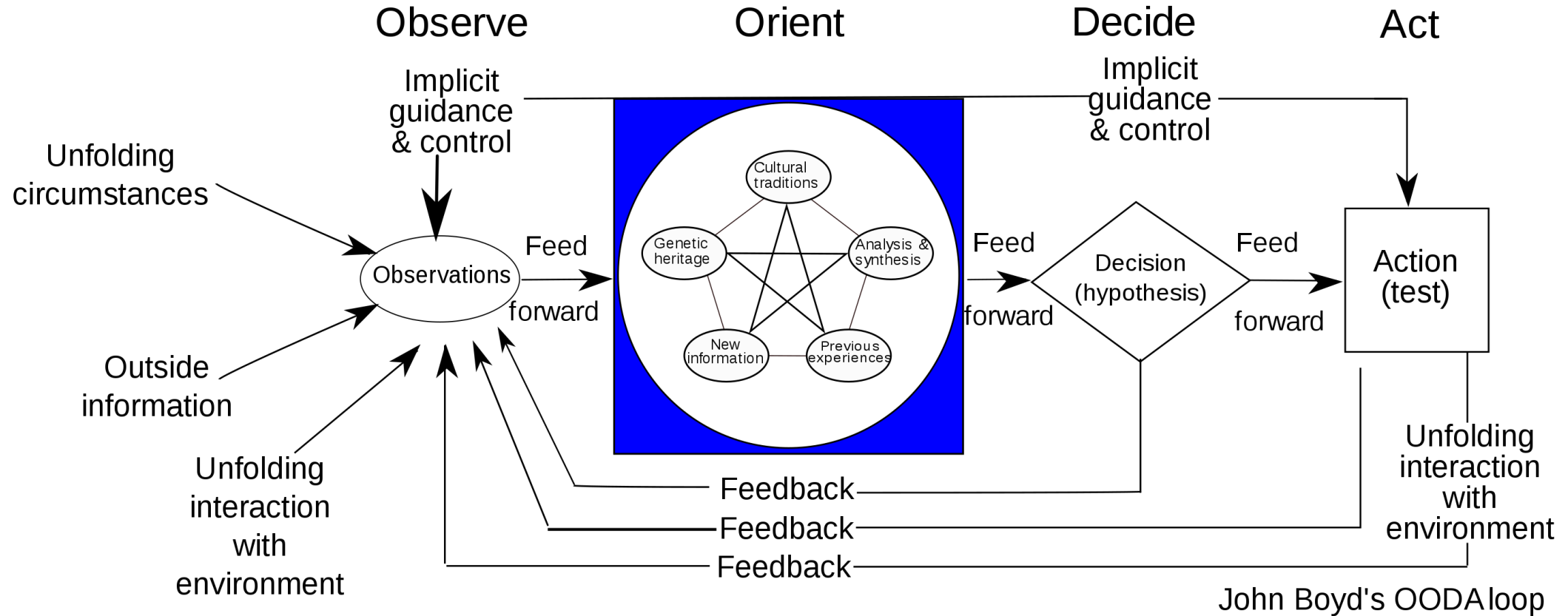
You MUST Measure It to Know It; you MUST Predict It to Understand It!



We Follow the Scientific Method



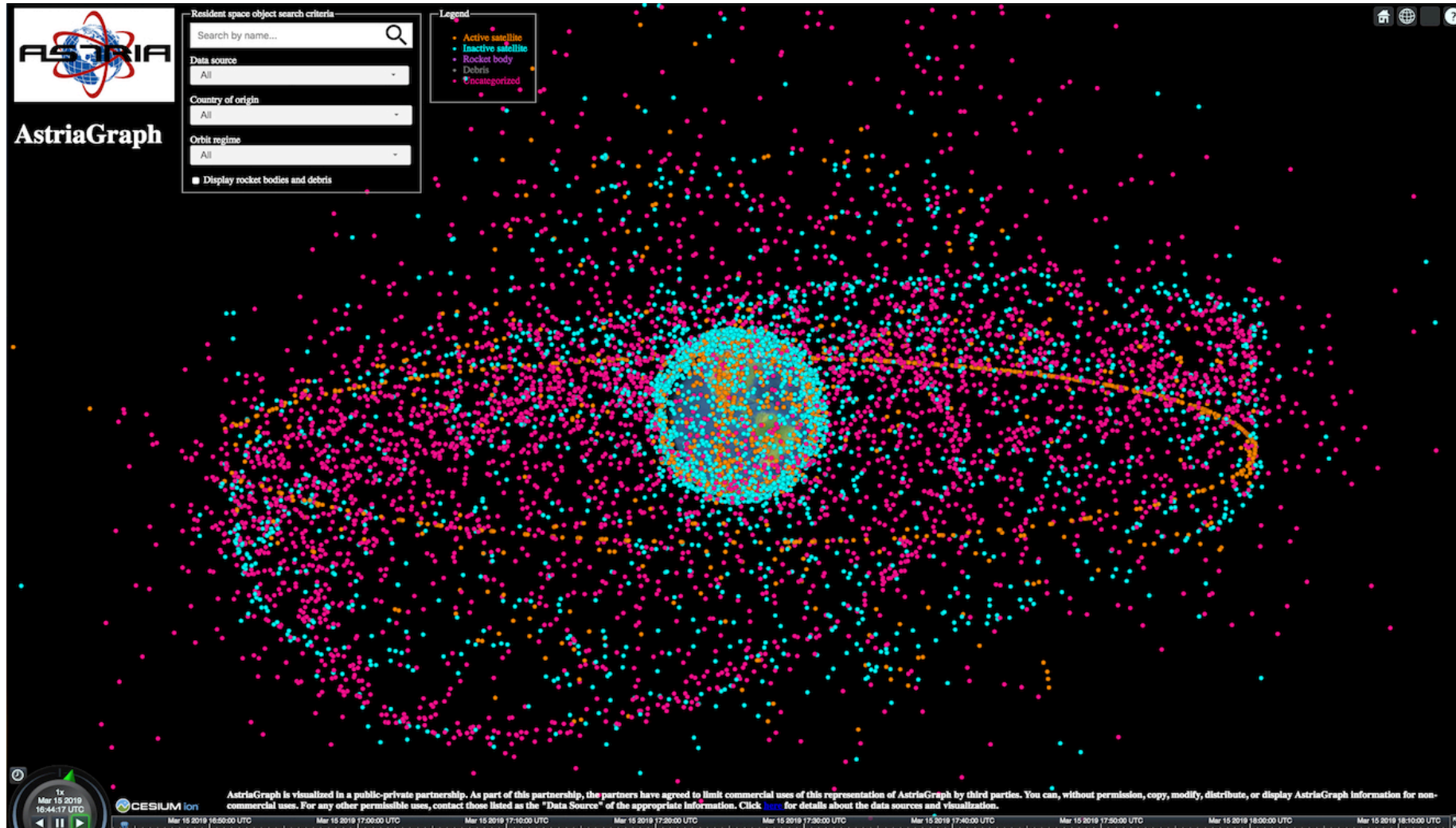
Observe – Orient – Decide – Act (OODA)



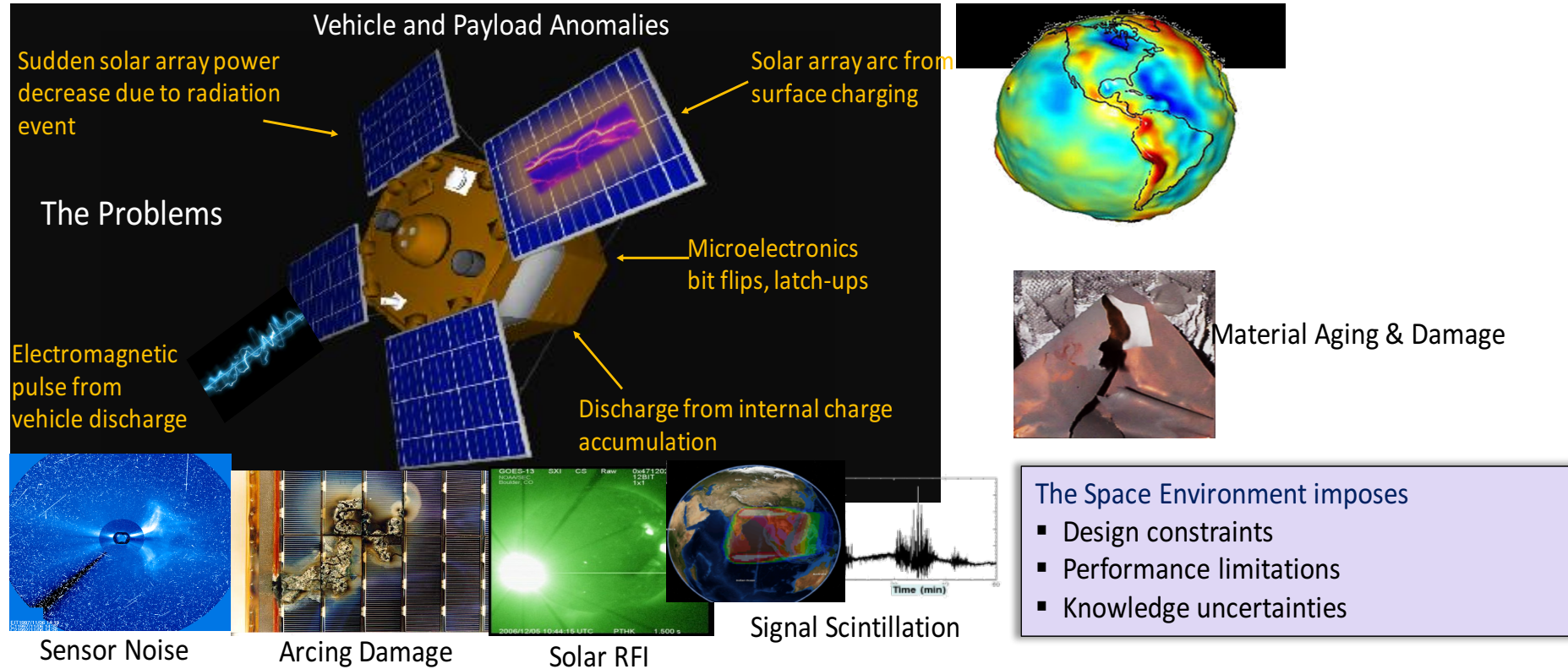
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Currently Tracked Resident Space Object Population



Space Environment Effects and Impacts



We apply time and effort to operate through the space environment impacts. They are a background noise that could conceal real threats.



Anomaly Attribution

Halloween 2003 Storms Retrospective Analysis*

CYBER ATTACK?

RHESSI – spontaneous reset of CPU (3x)
GOES 8 – unrecoverable shutdown of X-ray sensor
Landsat – all instruments turned off or safed
Cluster – some of four spacecraft CPU's reset
Mars Odyssey – MARIE instrument has temperature “red alarm” and is powered off; never recovered

JAMMER ATTACK?

MER 1, MER 2 – Entered sun idle mode after excessive star tracker events
Kodama – safe mode triggered by increased noise on Earth sensor, recovered 10 days later

DIRECTED ENERGY ATTACK?

GOES-12 – magnetic torquers disabled
CHPs – spacecraft tumbled, later recovered
Inmarsat – two spacecraft had speed increases on momentum wheels requiring firing of thrusters
POLAR – despun platform went out of lock 3x; auto recovery after each event
FedSat – stabilized platform started wobbling

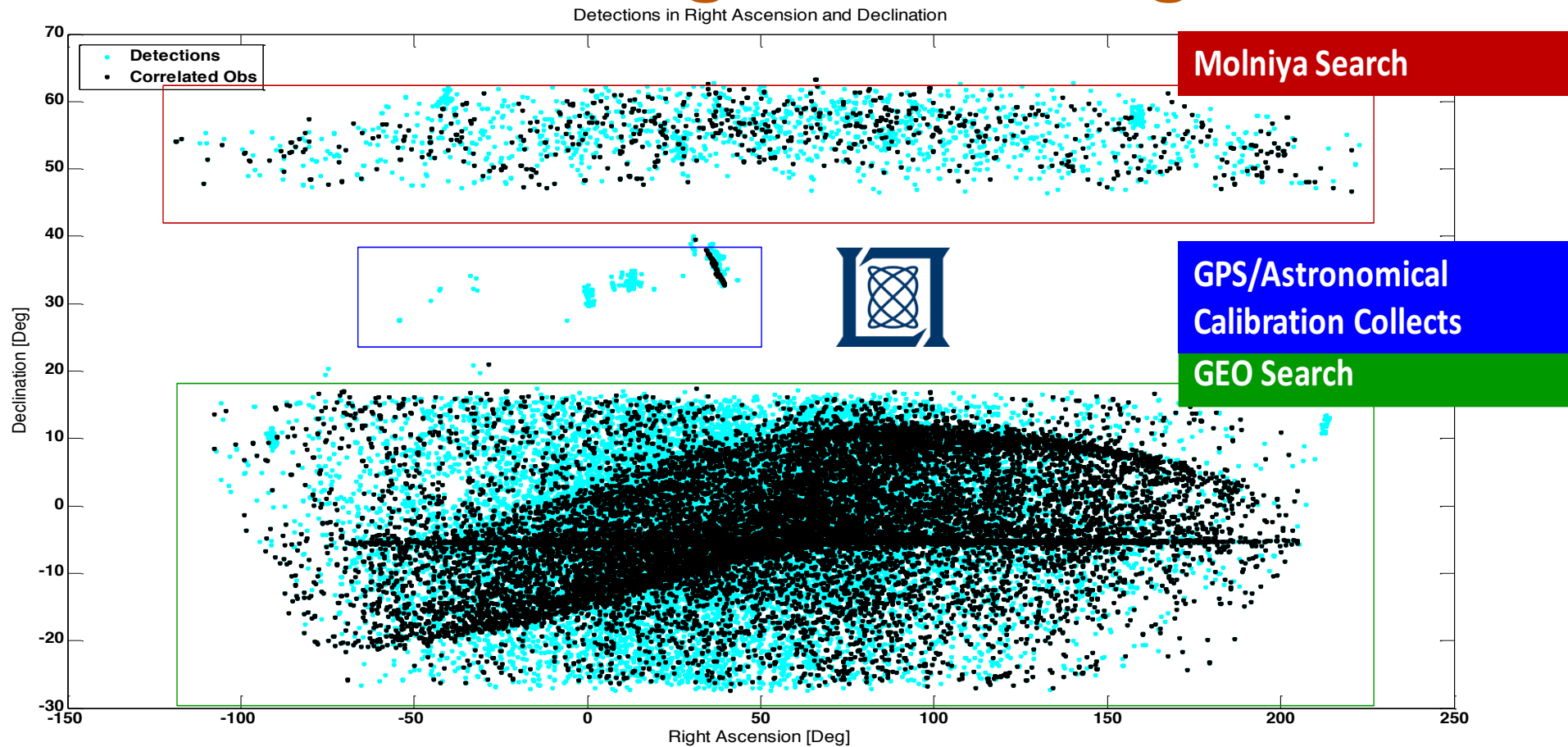
COATER SYSTEM ATTACK?

Midori – power dropped, entered safe mode; telemetry lost; total loss
GOES – Electron sensors saturated
GALEX – two UV experiments turned off due to high voltage caused by excessive charge
Chandra – build-up of grease on an optical filter in front of one cameras

*From: Susan Andrews, “Distributed Threat Warning Study”, MIT/LL Conference



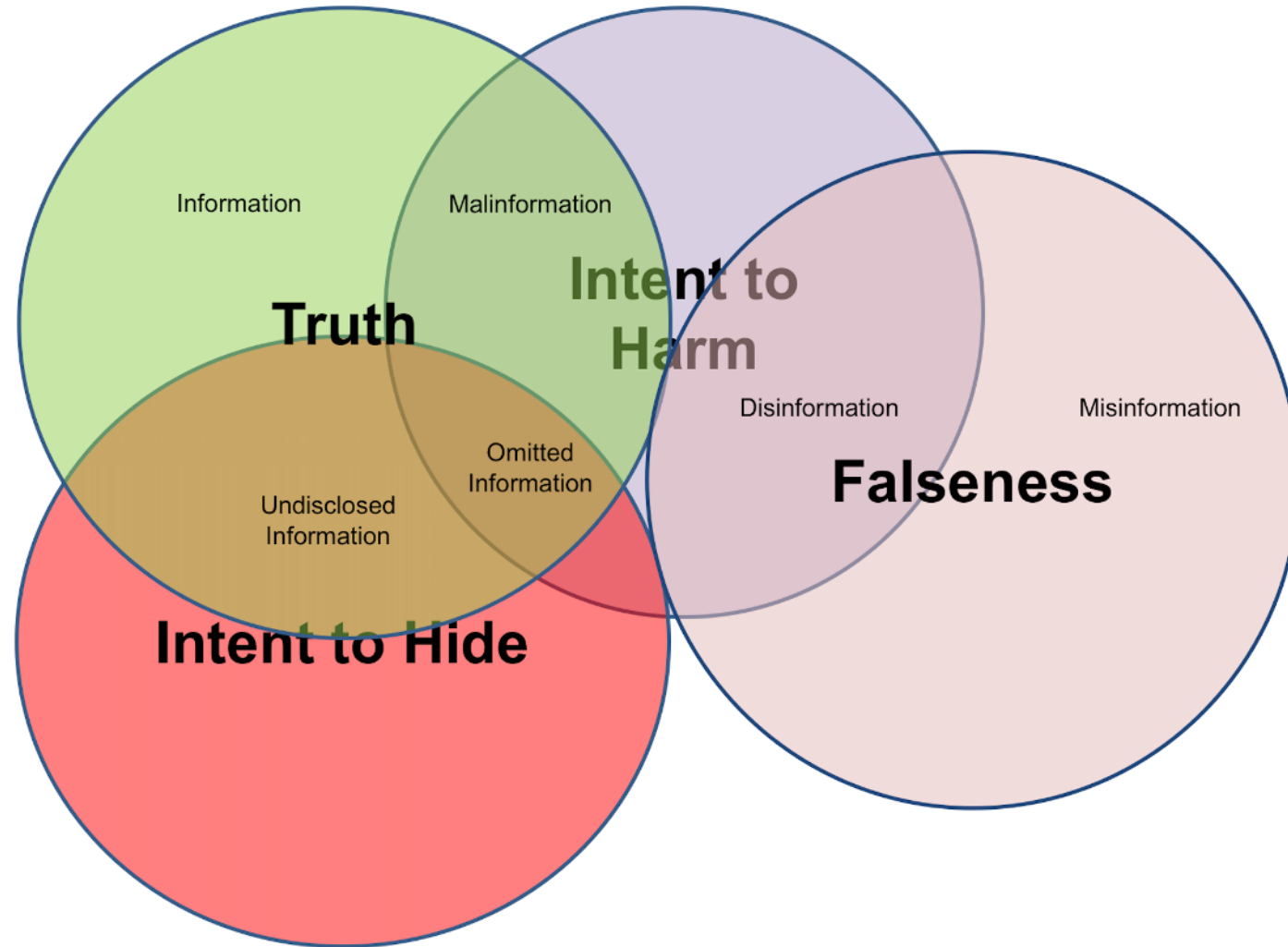
Detecting Vs Tracking



Synoptic search produces > 10k observations on 1000's of targets nightly



Information/Data Categories Venn Diagram



Confirmation Bias



- Tendency to search for, interpret, favor, and recall information in a way that confirms one's preexisting beliefs or hypotheses, while giving disproportionately less consideration to alternative possibilities
- Many of those who've contributed to the present-day problems are the only ones who have access to provide solutions

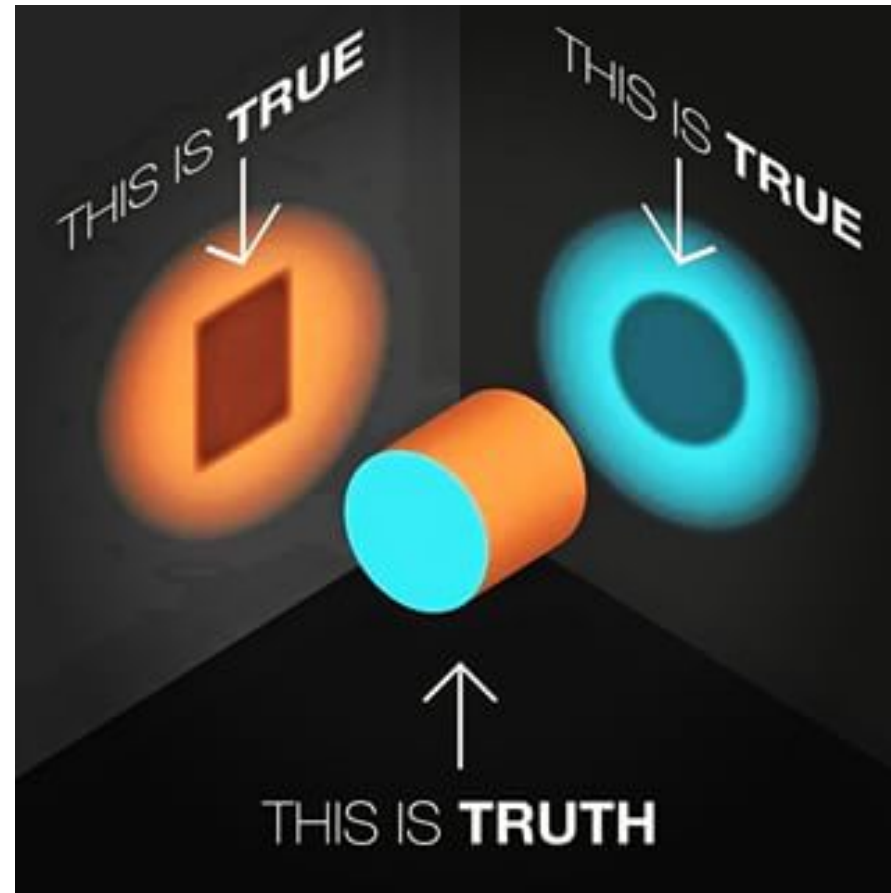


What Would an Adversary Do?

- Look like noise (we don't tend to characterize the structure in noise)
 - Use ambiguity to cover/conceal actions
- Look like an outlier (we tend to be quick to throw away data that disagrees with our hypotheses)
 - Act blatantly and/or non-sensically



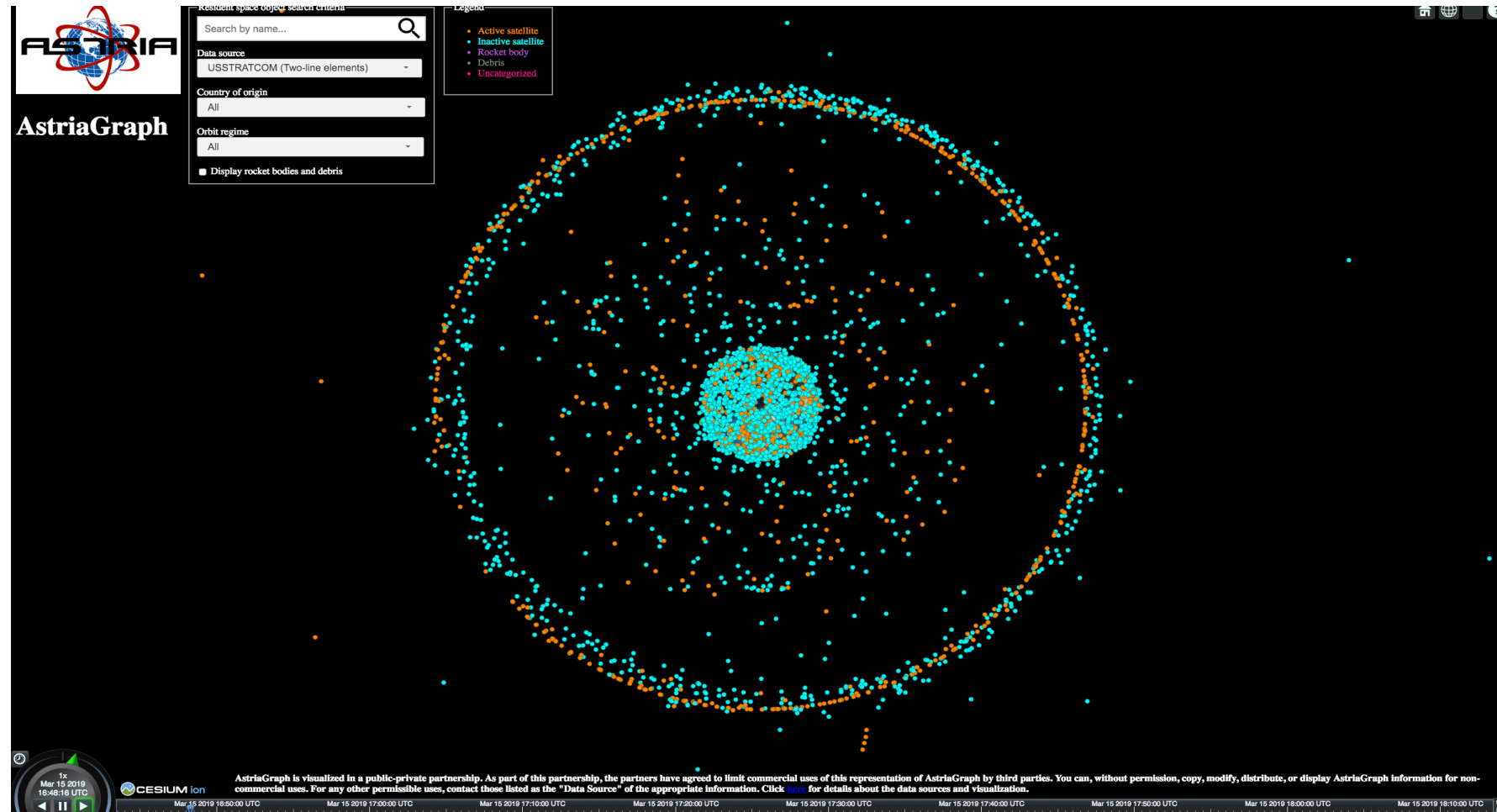
What Happens When We Don't Share Information? Partial Knowledge Can Lead to Wrong Decisions



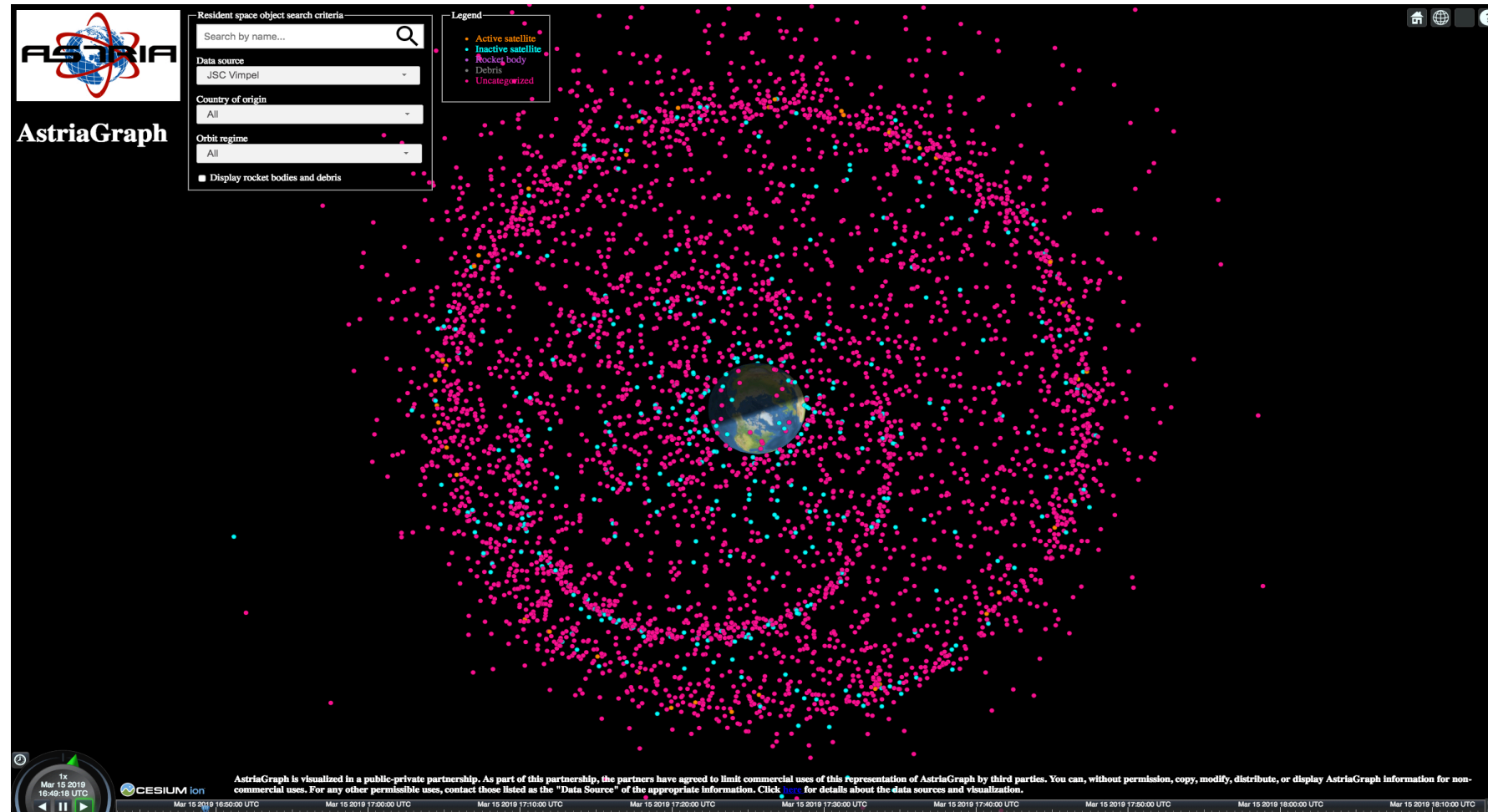
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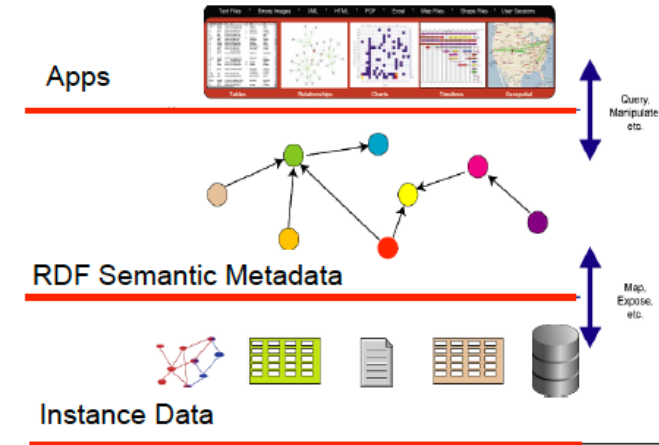
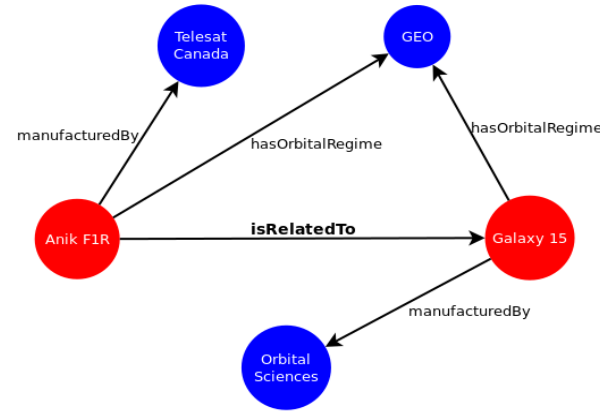
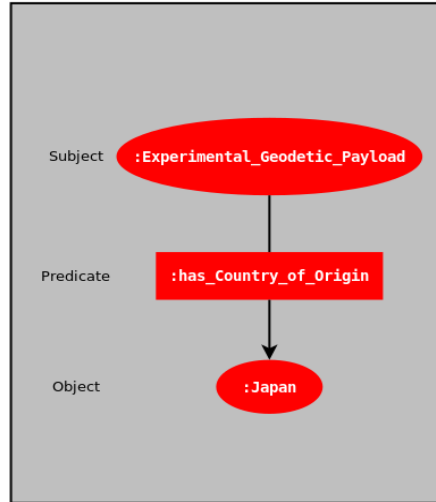
U.S. Public “Truth”



Russian Public “Truth”



Data Engineering, Modeling, Science, and Analytics



Problem Classification	Sample Problem
Anomaly Detection 	Given demographic data about a set of customers, identify customer purchasing behavior that is significantly different from the norm
Association Rules 	Find the items that tend to be purchased together and specify their relationship – market basket analysis
Clustering 	Segment demographic data into clusters and rank the probability that an individual will belong to a given cluster
Feature Extraction 	Given demographic data about a set of customers, group the attributes into general characteristics of the customers

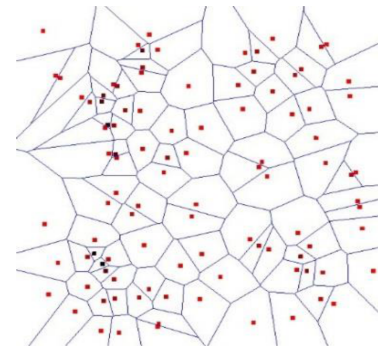
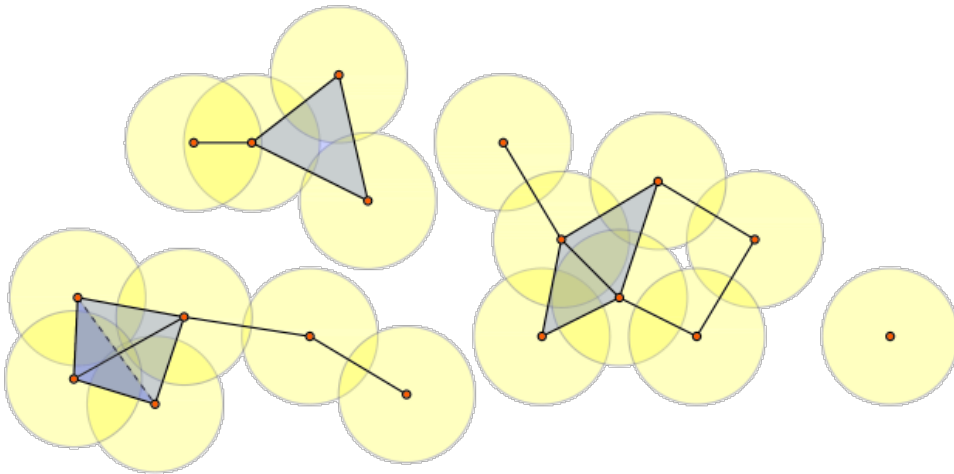
Images from Oracle



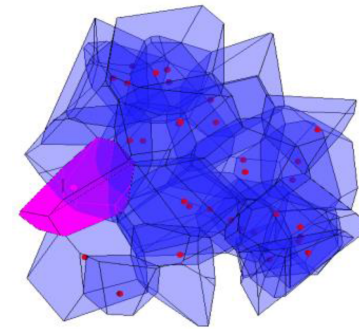
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From Data to Discovery: Patterns in the Graph

- Discovering "Latent Knowledge"
- Our framework facilitates multi-source information curation and analytics to identify correlations
 - One must ask the right question (make the correct query)
- Find which correlations have causal relationships
- Link these data (e.g. Vietoris-Rips Complex, Voronoi Diagrams, K-Means Clustering)



(a)



(b)



Quantify, Monitor, and Assess Space Activities

- You can't enforce a law that you can't measure
- Are space actors behaving according to agreed upon norms or guidelines?
- Who's following the law and who is not?
- Who's compliant with a policy or guideline and who isn't?
- How would you know?
- What's the body of evidence required to know?
- How do we make space transparent?



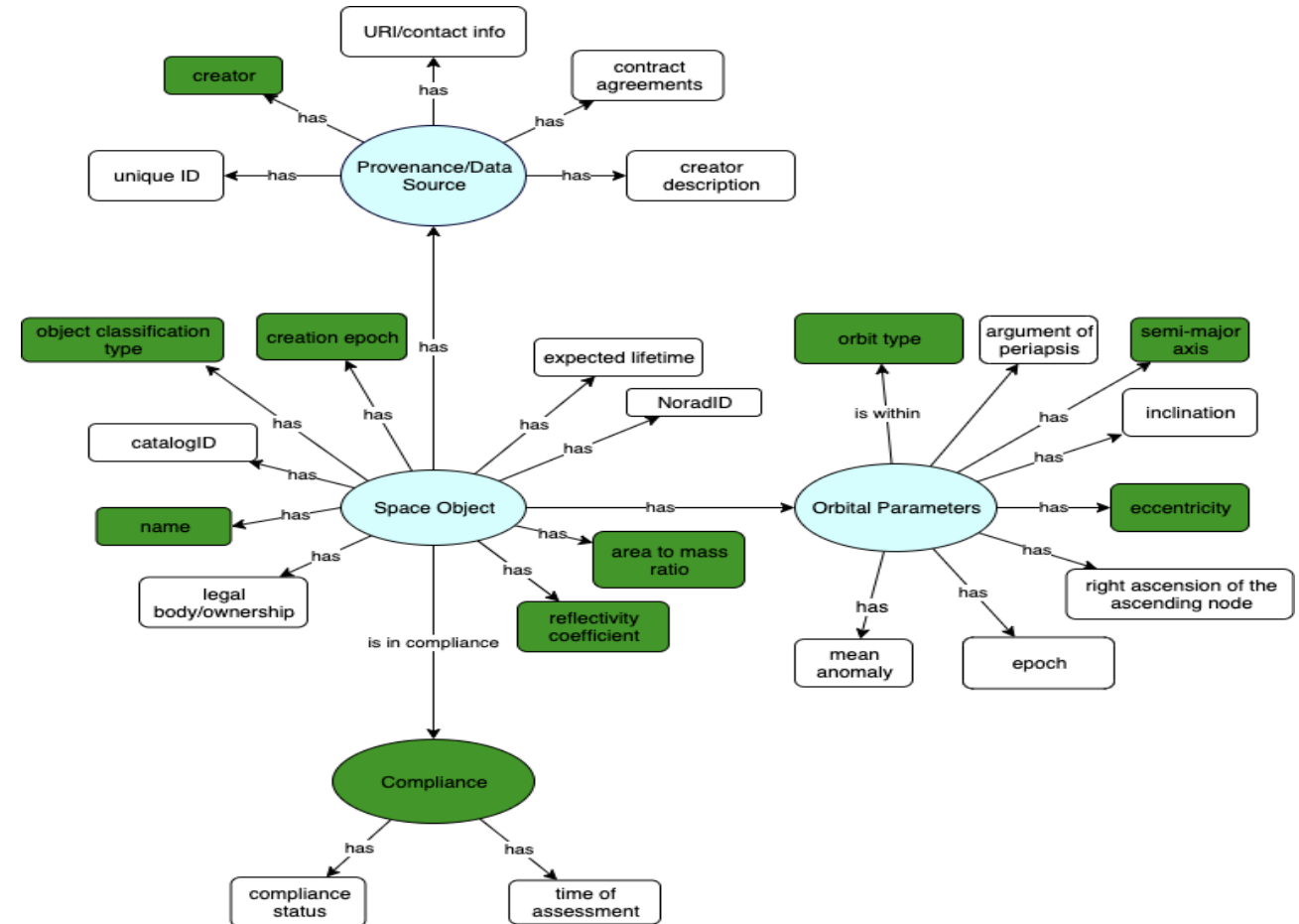
Multi-Source Information Fusion Example: Compliance with GEO Disposal Guidelines

- Leverages knowledge graphs
- Makes use of multi-source information
- Asks some key questions:
 - Is the object an intact satellite or rocket body?
 - Is the object subject to the guideline? (i.e. did the disposal guideline pre-exist?)
 - Is the RSO in the near GEO regime?
 - Is it's orbit compliant with the guideline(s)?
 - Is there evidence that it also complied with other end-of-life guidelines? (e.g. passivation)



Assessing and Monitoring for Compliance

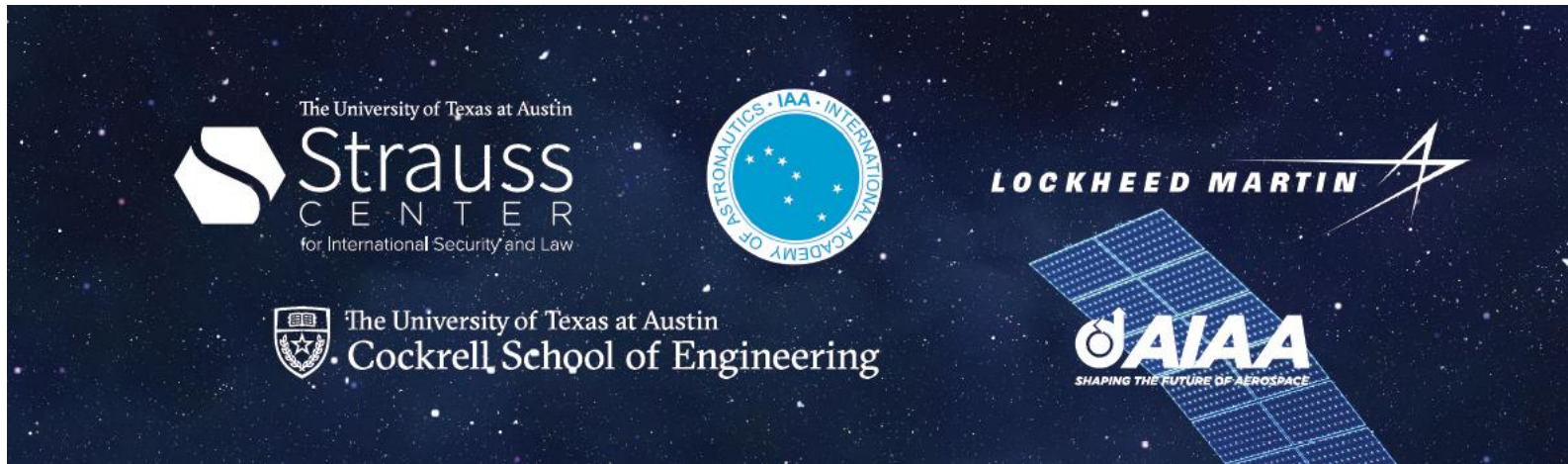
Question	Query	Results	Time (sec)
Which satellites have been compliant since a given year?	FROM space objects, compliance SELECT space object WHERE {space object compliance row = compliant, space object date >= year}	637	2
How many satellites are currently in GEO disposal compliance that are reported by a given data source?	FROM data sources, space objects, compliance SELECT space object WHERE {space object compliance row = true, data source = source}	637	2
Which satellites are compliant or noncompliant and owned by a given legal ownership?	FROM space objects, compliance SELECT space object WHERE {space object compliance row = compliant, space object country = legal body ownership}	133	1.3



<http://astria.tacc.utexas.edu/compliance>



IAA/UT Austin Space Traffic Management Conference



<https://www.strausscenter.org/item/2027-2020-space-traffic-management-conference.html>



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**“The problem with the world is that the stupid are
cocksure and the intelligent are full of doubt”**

Bertrand Russell

Questions?

<https://sites.utexas.edu/moriba>





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